Effectiveness of Robotic Exoskeleton-assisted Gait Training in a Patient with Guillain-Barré Syndrome: A Case Report

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길랭-바레증후군 환자에서 외골격 로봇 보조 보행 훈련의 효과: 증례보고

문보라 · 장윤철 · 김산하 · 정원형 · 박형규 · 송민근 · 최인성 · 한재영

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Abstract

An 80-year-old man diagnosed with Guillain-Barré syndrome (GBS) 8 years ago visited our clinic. He complained of gait disturbance with motor weakness and postural instability. Muscle strength of both lower limbs was good grade. He walked independently under supervision, but had difficulty walking a long distance. Eight weeks of robotic rehabilitation using powered robotic exoskeleton-assisted gait training (REGT) was programed for the patient. The REGT program consisted of sit-to-stand exercise, stand-to-sit exercise, and over-ground walking on a flat hallway. After 8 weeks of training, the patient showed improved balance function in three-dimensional dynamic posturography and kinematic gait patterns. Although energy cost and energy efficiency aggravated 4 weeks after the training, the exoskeletal gait training may be beneficial for improving balance function and kinematic gait pattern in GBS patients.

Key Words

Guillain-Barré syndrome, Exoskeleton, Gait training, Cardiopulmonary function

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Introduction

Guillain-Barré syndrome (GBS) is an uncommon neurological disorder in which the immune system erroneously attack the peripheral nervous system (PNS). The annual global incidence of GBS is reported to be approximately 1-2/100,000 person-years.[1]

The core clinical feature of GBS is rapid progressive bilateral motor weakness and the maximum motor weakness lasts for 2 to 4 weeks. Moreover, the duration of the plateau period variable. After plateau, most patients experience a nearly full recovery and return to their prior level of function; however, severely affected patients remain unable to walk or are fatigued.[2] Reduced muscle strength, sensory deficit, pain, and fatigue are the major sequela of GBS. Residual deficits impair patients' daily activities and quality of life.

Intravenous immunoglobulin and/or intravenous methylprednisolone and plasma exchange are be effective methods to impede disease progression. Simultaneously, supportive treatment, such as physical therapy (PT), occupational therapy, and pulmonary rehabilitation, are also performed. A previous systemic review; has shown that PT, including walking, cycle ergometer exercise, and cycling, may improve physical outcomes and significantly reduces disability in patients with GBS.[3]

Robot-assisted gait training is one type of PT; currently, it is gaining popularity because of its easy accessibility. However, most studies on robotic rehabilitation have been carried out in patients with central nervous system injuries such as stroke and spinal cord injury. Few studies have been conducted in patient with peripheral neuropathy (PN). Especially, researches on robotic rehabilitation using powered robotic exoskeleton in GBS patients are limited. In one case, exoskeleton was used for supplementary rehabilitation therapy that focused on upper extremity power and active range of motion.[4] Here, we report therapeutic outcome of robotic exoskeleton-assisted gait training (REGT) in a patient with GBS.

Fig. 1. Robotic exoskeleton-assisted over ground walking training. (A) Gait training wearing Angelegs, anterior view. (B) Gait training wearing Angelegs, posterior view.

Case Report

An 80-year-old man who was diagnosed with GBS (acute motor and sensory axonal neuropathy, AMSAN type) eight years ago visited our clinic. He complained of gait disturbance with motor weakness and postural instability. Both lower extremities manual motor test was good grade (MRC grade 4), He could walk 100-meter under supervision, but he has difficulty in walking a long distance. Contracture was not observed in his lower limbs, but he complained of mild bilateral knee pain due to early osteoarthritis. He was informed about this clinical study, and he voluntarily participated in this REGT program.

All training sessions and functional assessment were conducted at the Chonnam National University Hospital Rehabilitation Center under the supervision of a physical therapist. The REGT program consisted of three 30-minute sessions per week for 8 weeks, and it was conducted on an outpatient basis. Each session had three parts: initial standing training for 5 minutes, including wearing and removing the exoskeleton, weight bearing and weight shifting exercises for 5 min, and walking on a flat surface of a hallway for 20 min while wearing the exoskeleton (Fig. 1). The walking speed during the training was adjusted to the patient's pace. In this study, the patient was trained using a robotic exoskeleton, Angelegs (Angel-Robotics, Seoul, Korea). Angelegs consists of hip, knee and ankle segments and which only the hip and knee joints are motorized. And its low impedance in joint motor and assistance methods support walking. Moreover, Angelegs can sense the motion intention of patient using the ground contact sensors in both soles. When patients start to walk, the sensor detects the moments of initial swing and ground contact. In the initial swing phase, assistive torque is generated and it applied to the hip and knee joint motors. As a result, Angelegs can assist the gait more precisely, and it allows the maximization of the effect of rehabilitation training. Furthermore, Angelges can support sit-to-stand, stand-to-sit movements, standing, and over-ground walking movement.

Functional assessment was performed by a physical therapist using manual muscle test (MMT), 10-meter walking test, a timed up-and-go test before (T0) and after training (T1), 4 weeks after training (T2) without the exoskeleton. Additionally, we determined EuroQol-5D (EQ-5D) score for measuring the health status. Three-dimensional dynamic posturography (PRO-KIN system, TecnoBody Srl, Dalmine BG, Italy); was conducted to assess balance function without the exoskeleton. The patient was asked to stand still for a while on the tilting board of the posturography instrument. Then, the average value of center of the pressure (COP) was measured along the anterior-posterior and medial-lateral axes. The standard deviation (SD) of COP indicates the range of the body sway, and a large value of SD suggests postural imbalance in patients. While wearing the exoskeleton, we also performed three-dimensional kinematic gait analysis (OrthoTrak, Motion Analysis Corporation, Santa Rosa, CA, USA) during gait to evaluate temporal and spatial gait characteristics. The patient was asked to walk wearing a portable gas analyzer (model K4B2, COSMED Srl, Rome, Italy) that measured the mean VO_2 levels and energy expenditure. The patient

Table 1. Changes of Functional Scales

	Before training (T0)	After training (T1)	4 weeks after training (T2)
MMT			
Right hip/knee/ankle (MRC grade)	4/4/4	4/4/4	4/4/4
Left hip/knee/ankle (MRC grade)	4/4/4	4/4/4	4/4/4
Balance			
Opened eyes			
Standard forward-backward deviation (mm)	7	2	2
Standard medial-lateral deviation (mm)	6	1	1
Closed eyes			
Standard forward-backward deviation (mm)	13	7	7
Standard medial-lateral deviation (mm)	14	6	7
10-meter walking test			
Time taken at a comfortable pace (sec)	11.33	11.31	11.29
Time taken at a fast pace (sec)	8.89	8.89	8.78
Timed up and go test (sec)	12.44	12.41	12.44

MMT: manual muscle test, MRC: medical research council

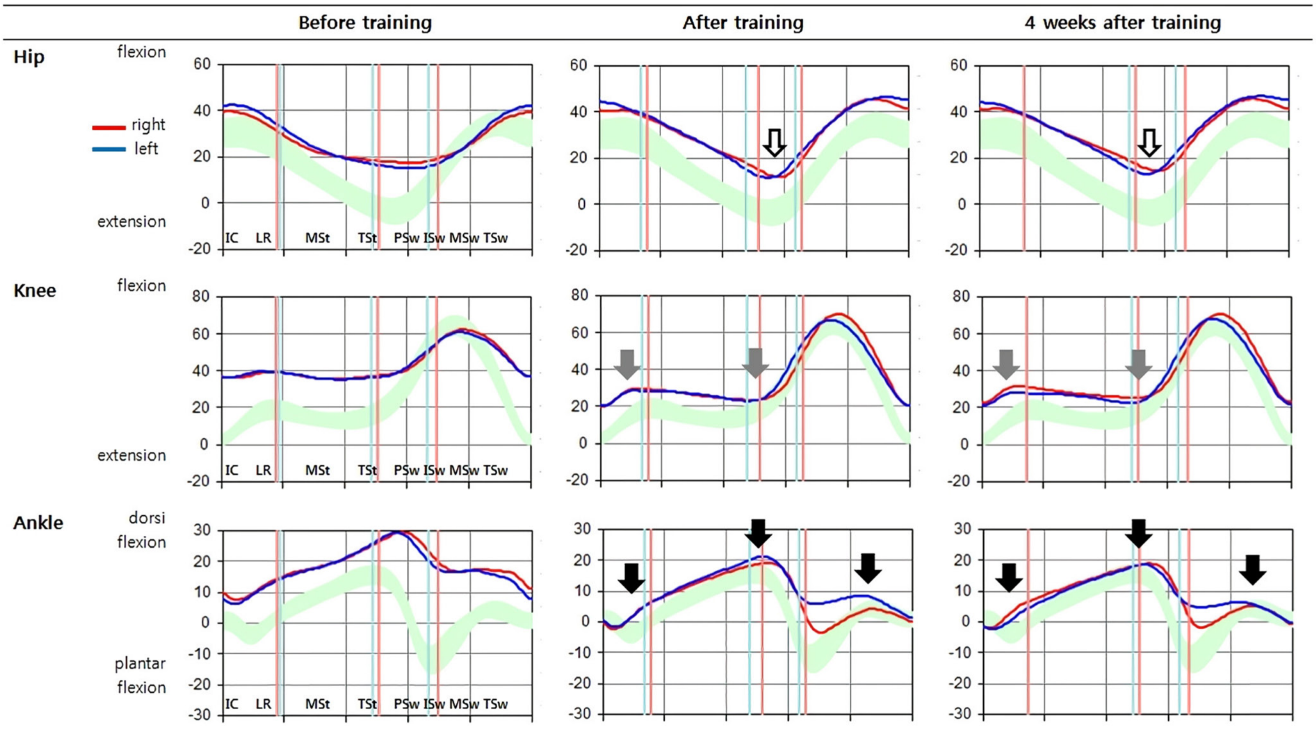

Fig. 2. This figure shows the kinematic data of gait analysis. After 8 weeks of robotic exoskeleton-assisted gait training, bilateral angles of hip (white filled arrow) and knee (gray arrow) extension increased during the stance phase, and bilateral angle of ankle dorsiflexion (black arrow) increased during the entire gait cycle.
IC: initial contact, LR: loading response, MSt: mid stance, TSt: terminal stance, PSw: pre-swing, ISw: initial swing, MSw: mid swing, TSw: terminal swing.

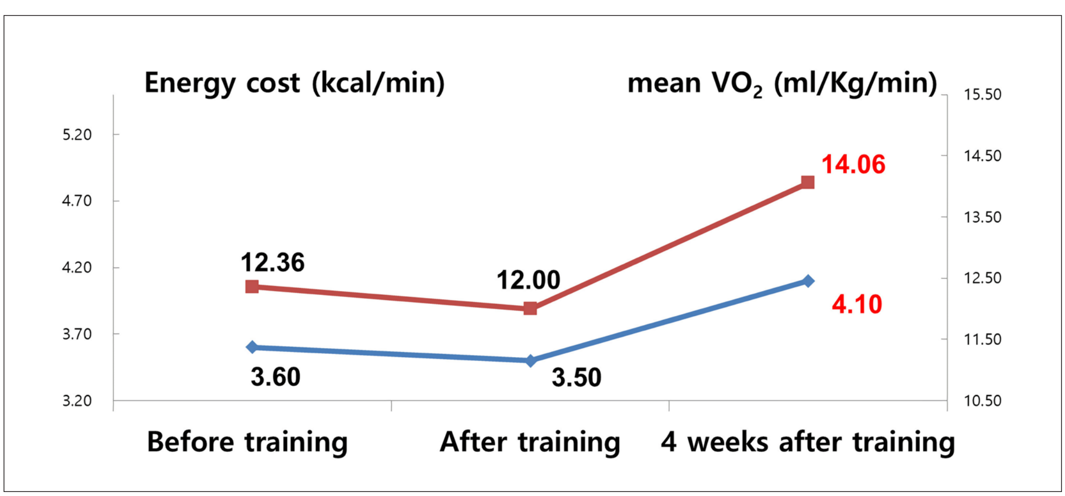

Fig. 3. Energy expenditure. There were no significant differences in VO_2 and energy cost measured before and after training. However, mean VO_2 and energy cost were higher 4 weeks after the training compared to those before training.

walked at a comfortable pace on a flat surface of an aisle. The following formula was used to calculated the energy cost, which is an indicator of the gait efficiency and cardiopulmonary fitness.[5]

The patient visited our rehabilitation clinic 6 weeks after the end of the program and underwent all tests again. No adverse events were reported during the intervention. This study was approved by the Institutional Review Board of the Chonnam National University Hospital (CNUH-2019-036) and this study was supported by a grant from the Chonnam National University Hospital Biomedical Research Institute (BCRI-21061).

After intervention, MMT, gait speed, gait performance showed no change after training and at 4 weeks after training (Table 1). However, three-dimensional dynamic posturography showed a decreased in the SD of COP along the anterior-posterior and medial-lateral axes after the training, and training effect lasted until 4 weeks after the training ended. Gait analysis revealed an improvement in kinematic gait pattern (Fig. 2). Bilateral hip and knee angles of extension increased during the stance phase, and bilateral ankle angle of dorsiflexion increased during the entire gait cycle. Training effects on kinematic gait pattern lasted until 4 weeks after the end of the program. Regarding cardiopulmonary function, there was no significant difference between mean VO_2 at T0 and T1, but mean VO_2 and energy cost at T2 were higher than those at T1 (Fig. 3).

Discussion

Individuals affected by GBS have difference prognosis. Six months after the onset of the disease, about 20% patients are unable to walk without help.[1,6] The most common residual symptoms are generalized motor weakness, sensory loss, fatigue and pain, which affect the quality of life and activities of daily living among survivors of the chronic GBS.[7] In our case, eight years after diagnosed of, the patient still complained of reduced endurance and walking distance. In terms of onset age of GBS, the GBS in elderly has several different clinical characteristics compared to general GBS in non-elderly patients. GBS in elderly has a relatively long hospital stay, a high incidence of pneumonia, and this led to show poorer prognosis than non-elderly patients.[8] Given the characteristics of the elderly, the treatment of GBS in elderly may require a different perspective.

PT is known to be effective in chronic GBS patients. One controlled study reported positive effects of PT intervention in 79 patients with chronic GBS who underwent 12 weeks of high-intensity outpatient rehabilitation. In that study, the high-intensity rehabilitation group had been diagnosed with GBS 4.4 years ago in average, which means that this group was in chronic stage. After 12 months of rehabilitation, the FIM score, especially for mobility/transfer and locomotion, improved 12 months after the rehabilitation.[9] Konstantinos et al. also reported a case of late recovery of GBS patient. In that case, the patient did not show significant improvement until first 1 year, but the patient showed massive enhancement after 1 year.[10] Moreover, it is known that patients with GBS may experience slow recovery up to 6 years, even though the patient is in plateau of neurological symptoms.[11] The results of our study are consistent with those of the previous study, indicating that rehabilitation may be necessary not only for the treatment of acute GBS but also for the reconditioning of patients with chronic GBS. In our study, exoskeleton gait training, a type of PT, resulted in improvement in the balance function assessed by posturography; the improvement lasted until 4 weeks after the end of the intervention.

It is noteworthy that the gait pattern of the patient was improved. The kinematic gait analysis revealed that the patient could walk relatively normally after training compared to before training. Moreover, this feature lasted until 4 weeks after the intervention. It is known that loss of normal gait pattern may restrict personal independence, affect the quality of life, and can be precursors of falls, which can result in severe injuries in the elderly.[12] Although there was no notable difference in muscle power and gait speed, the results that the gait pattern of our patient got relatively improved suggests potential effectiveness of exoskeletal gait training in GBS patient.

Initially, the patient was expected to use less energy for the same activity than that before the training in terms of cardiopulmonary function. After the training, there were no notable differences in gait speed, mean VO_2, and energy cost measured at T1 and T0. However, the mean VO_2 at T2 was higher than that at T1 at similar gait speed, indicating a worse energy efficiency. This aggravation of energy efficiency may be due to the insufficiency of training period, excessive correction of gait pattern, or detraining effect after the end of the training. Four weeks of training program may not be enough to adapt in normal gait pattern for the chronic GBS patient. In other respects, oxygen consumption may have increased at the same walking speed due to the detraining effect.

Montini et al.[4] reported a potential benefit of robotic rehabilitation in GBS patient by applying an assistive exoskeleton in upper extremity. In that study, the rehabilitative intervention consisted of multidisciplinary rehabilitation training such as physiotherapy, occupational therapy, physical conditioning, psychological support as well as exoskeletal training. Unlike previous study used the exoskeleton as a supplementary device to conventional rehabilitation, our case assessed the only effect of exoskeletal rehabilitation. As a result, we could check the improved balance function of GBS patient after rehabilitation program. In addition to other preceding studies about the effect of Angelegs in central nervous system disorder,[13,14] this case seems to suggest the clinical feasibility of Angelegs in patient with GBS.

Given the variety of clinical symptoms of GBS and intervention methods, further research to determine the most effective rehabilitation maneuver to facilitate reconditioning of patient with GBS and to reduce associated sequelae is required. Furthermore, controlled studies on the effect of exoskeleton gait training in patient with GBS are needed.

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